08773-21-A

HUMAN PERFORMANCE CENTER
DEPARTMENT OF PSYCHOLOGY
The University of Michigan, Ann Arbor

First Annual Report: Human Information Handling Processes (Contract AF 49(638)-1736)

ARTHUR W. MELTON
Principal Investigator

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Memorandum Report No. 4
June 1968

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THE UNIVERSITY OF MICHIGAN

COLLEGE OF LITERATURE, SCIENCE AND THE ARTS

DEPARTMENT OF PSYCHOLOGY

First Annual Report

HUMAN INFORMATION HANDLING PROCESSES

Arthur W. Melton

Principal Investigator

ORA Project 08773

under contract with:

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

BEHAVIORAL SCIENCES DIVISION

CONTRACT NO. AF 49(638)-1736

WASHINGTON, D. C.

Sponsored by

ADVANCED RESEARCH PROJECTS AGENCY

BEHAVIORAL SCIENCES, COMMAND AND CONTROL RESEARCH

ARPA Order No. 461, Amendments No. 3 and 5

administered through:

OFFICE OF RESEARCH ADMINISTRATION ANN ARBOR

June, 1968

SYNOPSIS

This is the first annual report of research carried out on human performance in information processing and memory at the Human Performance Center, Department of Psychology, University of Michigan, under Contract No. AF 49(638)-1736. Experimental results and theoretic progress are presented on the following topics: Taxonomy of information handling processes; selective information handling processes (which includes selective responding to stimuli, human adaptive capacities in optimizing performance, and decision theoretic interpretations of information processing performance); information storage and retrieval (which includes modeling of short-term memory); refinement or resolution of certain critical issues; and refinement of short-term-memory methods and measures.

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I. OBJECTIVES OF CONTRACT PROGRAM

This is the first annual report for the period 1 Jun 1967 through 31 May 1968 on Contract No. AF 49(638)-1736 which is currently funded for the period 1 Jun 1967 through 31 May 1969. This contract continues the research program on Human Performance in Information Handling and Storage which extended from 1 Jun 1963 through 31 May 1967 under Contract No. AF 49(638)-1235. One of the general objectives of the original contract and the present contract was to establish, in a University environment, a permanent research facility for the investigation of human performance capabilities and limitations that are of importance for the performance of men in a wide variety of man-machine systems. With the support for such an effort by these contracts, the Human Performance Center of the Department of Psychology, University of Michigan, was established in 1963 and has now become a stable federation of experimental and mathematical psychologists interested in advancing knowledge about man's information processing activities in perceiving, remembering, skillful manipulation of controls, and decision-making. Over time the effort within this contract program within the Human Performance Center has been directed more and more to the perceiving and remembering functions, with increasingly heavy emphasis on cognitive and intellectual factors and skills, in large part because support was obtained for the research of Professor Pew on perceptual-motor skills from NASA, and for Professor Edwards' research on decision processes from elements of the Air Force, from NASA, from USPHS, and elsewhere. However, the research environment in which the present contract work is conducted is intended to be inclusive of all principal functions that man performs in information handling, and will achieve this inclusiveness in the summer of 1968 with the addition to the staff of the Center Associate

Professor David H. Krantz, who is concerned especially with the investigation and mathematical modeling of sensory and perceptual processes, and of Associate Professor James G. Greeno, who is concerned not only with problems of perceiving and remembering but also, and particularly, with problems of concept utilization, thinking, and problem solving.

This consortium of scientists engaged in research on one or another aspect of the general problem of human information handling processes has resulted in a healthy intermixing of the theoretical notions and methodologies of different areas of specialization within human experimental psychology. This has, in turn, resulted in the production of new Ph.D.-level scientists at the University of Michigan who are broadly based in theory and method appropriate to the investigation of human information handling processes and committed to careers of research or research and teaching on such problems.

The specific objectives of research under Contract No. AF 49(638)-1736 are stated as follows in the Contract:

> a. Taxonomy of information handling processes. This effort will seek to improve knowledge of the ways of classifying types of information and information inputs, storage and processing activities required, and types of measures of outputs relevant to information processing systems.
>
> b. Selective information handling processes. This will include research on searching, filtering, transmitting, and condensing information and on human adaptive capacities in optimizing performance relative to the probability and significance of information components.
>
> c. Information storage and retrieval (memory). This will include work on development of a quantitative model of human short-term memory, resolution of critical issues in the theory of human memory, refinement of short-term memory methods and measures, and determination of the contribution of short-term memory to performance in information processing and decision-making tasks.
>
> d. Work on the organization and synthesis of knowledge regarding human information handling processes.

Publications, papers presented at scientific meetings, and other major work accomplished toward these objectives are reported in Section III, entitled "Technical Program." Accounting for technical effort and expenditures, equipment development, and future operational plans are reported in Section II, entitled "Operations."

II. OPERATIONS

Technical Effort

All technical effort on the project is not chargeable to the project, either because of optional use of University-paid research time on the project by the senior scientists, support of senior scientists on Fellowships for study in the Human Performance Center, or support of junior scientists (graduate research assistants) by graduate fellowships or traineeships supplied by other agencies (e.g., NSF, NIH). Therefore, the accounting of technical man-months is made separately in Table 1 for those charged to the contract and for those not so charged.

TABLE 1

MAN MONTHS OF TECHNICAL EFFORT

Project Staff	Period 1 Mar 68 - 31 May 68			Cumulative: 1 Jun 67 - 31 May 68		
	Charged to Contract	Not Charged	Total	Charged to Contract	Not Charged	Total
Senior Staff	2.20	4.00	6.20	16.25	15.00	31.25
Grad.Res.Asst.	18.30	5.50	23.80	102.30	17.50	119.80
Total	20.50	9.50	30.00	118.55	32.50	151.05

The total man-months of technical effort compares favorably with the estimates made in the proposal by P. M. Fitts and A. W. Melton in March, 1965, although the loss of Professor Fitts by death in May, 1965, has been qualitatively irreplaceable. The proposal estimated 25.75 man-months of paid senior staff effort; there was only 16.25 man-months of paid effort, but this was supplemented by 15.00 man-months of unpaid senior staff effort within which is included 1/2 time of A. W. Melton, the principal investigator, for the 9-mo. academic

year and full-time of Dr. John C. Jahnke (Associate Professor, Psychology, Miami University), who is working with Melton on a 12-month Special Post-Doctoral Fellowship from NIMH.

The total man-months of paid technical effort by M.A.-level research assistants and Graduate Research Assistants (102.50) exceeded the proposal estimate (75.0). Several students working on project tasks under the supervision of the senior staff were paid during the academic year by NSF pre-doctoral fellowships or NIH graduate traineeships, hence the 17.50 man-months of unpaid graduate research assistance indicated in the table.

During the reporting period, the following 7 consultants visited the project, reported their ongoing research related to project work, and advised us regarding specific aspects of our work:

Dr. David A. Grant, Professor of Psychology, University of Wisconsin
Dr. Steven W. Keele, Instructor in Psychology, University of Oregon
Dr. Geoffrey Keppel, Visiting Associate Professor of Psychology, Northwestern University
Dr. Robert E. Morin, Professor of Psychology, Kent State University
Dr. Michael I. Posner, Professor of Psychology, University of Oregon
Dr. Leo J. Postman, Professor of Psychology, University of California at Berkeley
Dr. Ernst Z. Rothkopf, Bell Telephone Laboratories

In the year ending 1 Jun 68, 10 graduate students completed or neared completion of doctoral dissertations on contract studies which had been initiated under the preceding Contract No. AF 49(638)-1235. The status of each of those studies is shown in Table 2.

TABLE 2

DOCTORAL DISSERTATIONS COMPLETED OR IN PROGRESS ON PROJECT TASKS DURING THE PERIOD 1 JUN 1967-31 MAY 1968

Student	Dissertation Topic or Title	Chairman of Committee	Present Status
Collins, A. M.	Repetition effects in visual short-term memory	E. J. Martin	In data analysis
Gelfand, H.	Interresponse times as a measure of idiosyncratic and normative organization in recall	A. W. Melton	In data analysis
Kamlet, A. S.	Temporal factors in the utilization of coding rules	I. Pollack	In data analysis
Ligon, E.	The effects of similarity on very-short-term memory under conditions of maximal information processing demands	A. W. Melton	Accepted and published as HPC Tech. Rep. No. 8, May, 1968. (Rept. 08773-19-T)
Lively, B. L.	The Von Restorff effect in very-short-term memory	A. W. Melton	In final editing
Pollatsek, A.	Relative roles of repetition, rehearsal and interference in short-term memory	R. Bjork	In data analysis
Reicher, G. M.	Perceptual recognition as a function of meaningfulness of stimulus material	A. W. Melton	Accepted and published as HPC Tech. Rept. No. 7, February, 1968 (Rept. 08773-17-T)
Rubin, S. M.	The effect of stimulus modality on proactive and retroactive inhibition in short-term memory	A. W. Melton	In final editing but see note
Swensson, R.G.	Experiments on choice reactions with continuous cost for time	W. Edwards	In final writing
Triggs, T. J.	Choice responses to two successive signals: The effect of instructional set, predictability of interval and S-R compatibility	I. Pollack	In final writing
Tversky, B.	Effects of retrieval task condition on selective encoding of information for memory storage	A. W. Melton	In data collection

Note: Owing to the death of S. M. Rubin in January, 1968, after completing the final draft of his dissertation, final editing for publication will be done by A. W. Melton

Fiscal Status

Planned and actual expenditures for the period 1 Jun 1967 through 31 May 1968 are shown in Table 3. No financial problems are anticipated during the second year of the contract.

TABLE 3

PLANNED AND ACTUAL EXPENDITURES BY QUARTERS

Quarter-Year	Quarterly Budget Planned	Quarterly Budget Actual	Cumulative Balance Planned	Cumulative Balance Actual
1 Jun 67-31 Aug 67	$72,000	$57,428	$356,374	$370,946
1 Sep 67-30 Nov 67	44,400	71,195	311,974	299,751
1 Dec 67-29 Feb 68	44,400	43,868	267,574	255,883
1 Mar 68-31 May 68	53,600	38,616	213,974	217,267
1 Jun 68-31 Aug 68	72,000		141,974	
1 Sep 68-30 Nov 68	44,400		97,574	
1 Dec 68-28 Feb 69	44,400		53,174	
1 Mar 69-31 May 69	53,174		0	

Equipment Developments

During the year two new equipment developments for the display of input information in studies of selective information processing and memory were completed, tested, and placed in use:

1. High-speed serial display device ("memory drum"). For some time there has been a requirement for a display device that would permit the presentation of verbal stimuli as short as a single letter or as long as a 10-word sentence in a linear array and for very brief intervals of time. The requirements related to the size of the display can be achieved with the standard Stowe "memory drum" of which we have several and with which most psychological laboratories are equipped. However, the Stowe drum, and its competitors, cannot be operated reliably at rates of greater than 2 stimuli

(turns of the drum) per second, and the time that the drum is in motion is a significant fraction of the display time. The unit that has been assembled to satisfy our requirement is composed of a Digimotor and an aluminum drum which is a component of a Brush recorder. Messages are typed on Brush paper. The drum moves 3/8 in. with each pulse to the Digimotor, and can be driven at the maximum rate of 25 steps (pulses) per second. The step time (moving time) is 30 msec. The drum may be driven by any device capable of generating a 3-volt pulse of 1 msec. duration. At present, this display device is being pulsed (in different experiments) by a paper-tape reader, a voice key, and magnetic tape.

2. BinaView Paper-Tape Display Device. A paper-tape reader and an alphanumeric BinaView with two "floating" colors (Industrial Electronic Engineers) have been combined to provide a very fast, flexible display device for sequences of single letters or digits, with or without color tinting. The punch-tape program for the tape reader controls the character presented, the presentation time of each element shown, the presence and kind of color, and various external devices which specify the correct response, take latencies from a voice-key or a push-button, and specify feedback to the operator.

Arrangements appear to have been completed for transfer of accountability of the Air Force PDP-1 computer to the present contract. The computer is in heavy use in on-line mode in a number of experiments being conducted as part of the contract work. All of these experiments (e.g., a study of choice reaction time with continuous cost for time, a study of the effect of massed and spaced presentations of words in continuous recognition memory, and a study of various levels of practice in discriminating members of arbitrary categories of letters on later performance in short-term memory experiments involving those letters) either demand on-line computer control of the task

or would be prohibitively expensive of time and data analysis funds if accomplished by conventional techniques.

Future Operational Plans

Dr. David J. Murray, currently Assistant Professor of Psychology at Queens University, Kingston, Ontario, will join the senior staff of the project for 11 months beginning July 1, 1968. He will be full time on the project except that during the period 22 Aug 1968-23 Apr 1969 he will serve as a half-time lecturer in the Department of Psychology. Dr. Murray has made extensive investigations of auditory and vocalization coding factors in short-term memory, and selective perceptual processes.

Professor David Krantz, Department of Psychology, University of Michigan, formally accepted an invitation to become a member of the staff of the Human Performance Center, effective 1 July, 1968. Professor Krantz is an outstanding young mathematical psychologist, especially interested in mathematical models of sensory and perceptual processes and theories of measurement, decision, and choice. Although no formal support by the project of Professor Krantz' research is contemplated during the term of the present contract, he fills an important gap in the staffing of the Human Performance Center and will be a resource person for staff and students working on the project.

Professor James Greeno, currently at Indiana University, has agreed to join the Department of Psychology and the staff of the Human Performance Center, effective 23 Aug 1968. Professor Greeno is an outstanding contributor to the mathematical modeling of learning, memory, and especially the complex forms of learning and problem solving (concept learning, thinking). His membership in the staff of the Human Performance Center further rounds out the coverage of important sub-areas of the human performance and information-

processing mission of the Center. Dr. Greeno's program of research requires computer-controlled information-displays and reaction-consoles. The University has made available to Dr. Greeno a fund of approximately $25,000 for purchase or rental of the equipment required for his work, and support in the amount of approximately $8,000 (in equipment rental or personnel services) will be provided from project funds during the period 1 Sep 1968 to 31 May 1969. It is anticipated that Dr. Greeno will participate in the preparation of the proposal to be submitted for the research program beyond 1 Jun 1969.

Dr. John A. McNulty, Associate Professor of Psychology, Dalhousie University, Halifax, Nova Scotia, will join the staff of the Center and Project for the period 1 Sep 1968 to 31 Aug 1969. Dr. McNulty, who obtained his Ph.D. with Professor Tulving at the University of Toronto in 1962, and has been exceptionally productive in research on verbal learning, short-term memory, and perceptual processes, is being supported by funds from Canadian sources. Most, if not all, of his work during the year will be in direct support of project objectives, and he will be provided with facilities, equipment and personnel support from project funds.

Three first-year graduate students in Experimental Psychology who will enter the University in August, 1968, have accepted Graduate Research Assistantships for work on project tasks under the supervision of the Senior Staff.

III. TECHNICAL PROGRAM

Publications

Publications in Print

During the period of this report 17 articles based on current work or work under the preceding Contract AF 49(638)-1235 appeared in scientific journals or the Human Performance Technical Report or Memorandum Report series. These are listed below. All publications have been given report numbers (e.g., 08773-19-T) appropriate to the local account number for Contract No. AF 49(638)-1736, but those previously indicated as products (in press, with no report number) of Contract No. AF 49(638)-1235 are preceded by an asterisk. Two of the publications have appeared since the Quarterly Letter Report dated 1 Mar 1968 (08773-18-L) and copies have not yet been transmitted. Copies of these reports (Ligon, Rept. 08773-19-T, and Martin, Rept. 08773-20-J) are attached to this report.

PUBLISHED REPORTS: 1 JUN 67-31 MAY 68

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*Bernbach, H. A. Stimulus learning and recognition in paired-associate learning. J. exp. Psychol., 1967, 75, 513-519. (Published version of Univ. Mich. Tech. Rept. 05823-7-T, August, 1965.) (08773-15-J)

*Crowder, R. G. Short-term memory for words with a perceptual-motor interpolated activity. J. verb. Learn. verb. Behav., 1967, 6, 753-761. (Published version of University Mich. Tech. Rept. 05823-3-T, December, 1964.) (08773-11-J)

*Egeth, H., & Smith, E. E. Perceptual selectivity in a visual recognition task. J. exp. Psychol., 1967, 74, 543-549. (08773-14-J)

*Goggin, J. P. First-list recall as a function of second-list learning method. J. verb. Learn. verb. Behav., 1967, 6, 423-427. (08773-07-J)

*Goggin, J. P. Retroactive inhibition with different patterns of interpolated lists. J. exp. Psychol., 1968, 76, 102-108. (08773-13-J)

Kahneman, D., Beatty, J., & Pollack, I. Perceptual deficit during a mental task. Science, 1967, 157, 218-219. (08773-04-J)

Kammann, R., & Melton, A. W. Absolute recovery of first-list responses from unlearning during 26 minutes filled with an easy or difficult information processing task. Proceedings Amer. Psychol. Assn., 1967, 63-64. (08773-05-J)

Ligon, E. The effects of similarity on very-short-term memory under conditions of maximal information-processing demands. Human Performance Center Technical Report No. 8, May, 1968. (08773-19-T)

*Martin, E. Stimulus recognition in aural paired-associate learning. J. verb. Learn. verb. Behav., 1967, 6, 272-276. (08773-02-J)

*Martin, E. Relations between stimulus recognition and paired associate learning. J. exp. Psychol., 1967, 74, 500-505. (08773-08-J)

Martin, E. Responses to stimuli in verbal learning. Human Performance Center Memorandum Report No. 3, October, 1967. (08773-09-M)

*Martin, E. Short-term memory, individual differences and shift performance in concept formation. J. exp. Psychol., 1968, 76, 514-520. (08773-20-J)

*Martin, E., & Roberts, K. H. Sentence length and sentence retention in the free-learning situation. Psychonomic Science, 1967, 8, 535-536. (08773-03-J)

*Pachella, R. G., & Pew, R. W. The speed-accuracy trade-off in reaction time: The effect of discrete criterion times. J. exp. Psychol., 1968, 76, 19-24. (08773-12-J)

Reicher, G. M. Perceptual recognition as a function of meaningfulness of stimulus material. Human Performance Center Technical Report No. 7, February, 1968. (08773-17-T)

*Smith, E. E. Effects of familiarity on stimulus recognition and categorization. J. exp. Psychol., 1967, 74, 324-332. (Published version of UM Tech. Rept. 05823-9-T, December, 1965.) (08773-06-J)

*Smith, E. E. Choice reaction time: An analysis of the major theoretical positions. Psychol. Bulletin, 1968, 69, 77-110. (Published version of Human Performance Center Tech. Rept. No. 6, 05823-13-T, January, 1967.) (08773-16-J)

Publications in Press

In addition, 5 articles, 2 of which were submitted prior to 1 Jun 1967, have been accepted for publication and are "in press" on 1 Jun 1968. These are listed on the following page.

REPORTS ACCEPTED FOR PUBLICATION AND IN PRESS ON 1 JUN 1968

Garskof, M. H. Short-term retention of paired-associates as a function of instructions and retention measure. J. verb. Learn. verb. Behav., in press.

Martin, E. Stimulus meaningfulness and paired-associate transfer: An encoding variability hypothesis. Psychological Review, in press.

Martin, E. Supplementary report: Recognition and correct responding mediated by first letter of trigram stimuli. J. verb. Learn. verb. Behav., in press.

Martin, E., Roberts, K. H., & Collins, A. M. Short-term memory for sentences. J. verb. Learn. verb. Behav., in press.

Roberts, K. H. Grammatical and associative constraints in sentence retention. J. verb. Learn. verb. Behav., in press.

Presentations at Scientific Meetings

Finally, with respect to formal communication of the products of the research program, there were oral presentations of research of the Contract at scientific meetings. These are listed below.

PAPERS PRESENTED AT SCIENTIFIC MEETINGS: 1 JUN 1967-31 MAY 1968

Bjork, R. A., & Abramowitz, R. L. The optimality and commutivity of successive intervals in short-term memory. Paper presented at the Annual Meeting of the Midwestern Psychological Association, Chicago, Ill., May 1968.

Goggin, J., & Martin, E. Stimulus encoding and retoactive inhibition. Paper presented at the Annual Meeting of the Midwestern Psychological Association, Chicago, Ill., May, 1968.

Kammann, R., & Melton, A. W. Absolute recovery of first-list responses from unlearning during 26 minutes filled with an easy or difficult information processing task. Paper presented at the Annual Meeting of the American Psychological Association, Washington, D. C., September, 1968.

Mackay, S. A., & Martin, E. Tachistoscopic manipulation of stimulus encoding variability in paired-associate learning. Paper presented at the Annual Meeting of the Midwestern Psychological Association, Chicago, Ill., May, 1968.

Martin, E. Word-class effects in sentence retention. Paper presented at Annual Meeting of the Psychonomic Society, Chicago, Ill., October, 1967.

Martin, E. Stimulus factors in verbal transfer. Paper presented in a symposium arranged by Section I (Psychology) at the Annual Meeting of the American Association for the Advancement of Science, New York, New York, December, 1967.

Melton, A. W. Short-term memory: I. Interference effects, and Short-term memory: II. Recognition memory. Invited lectures at NATO Advanced Studies Institute on Techniques and Results in the Assessment of Short-Term Memory, Cambridge, England, August, 1967.

Melton, A. W. Implications of proactive inhibition in short-term memory for the analysis of coding processes in memory. Paper presented at Symposium on Psychopathology of Memory, Dedham, Massachusetts, October, 1967.

Melton, A. W. Repetition and retrieval from memory. Paper presented at the Fall Meeting of the National Academy of Science, Ann Arbor, Michigan, October, 1967.

Melton, A. W. Memory and the learning process. Invited address to the American Educational Research Association, Chicago, Ill., February, 1968.

Melton, A. W., & Shulman, H. G. Further studies of a distributed practice effect on probability of recall in free recall. Paper presented at the Annual Meeting of the Psychonomic Society, Chicago, Ill., October, 1967.

Roberts, K. H. The Cloze procedure and determinants of recall. Paper presented at the Annual Meeting of the Midwestern Psychological Association, Chicago, Ill., May, 1968.

Shulman, H. G. The effects of word and categorical repetitions on free recall. Paper presented at the Annual Meeting of the Midwestern Psychological Association, Chicago, Ill., May, 1968.

Wattenbarger, B. L. Speed and accuracy set in visual search performance. Paper presented at the Annual Meeting of the Midwestern Psychological Association, Chicago, Ill., May, 1968.

Major Work Accomplished

Taxonomy of Information Handling Processes

A gross taxonomy of information handling tasks was developed under the preceding Contract No. AF 49(638)-1235 and has been used beneficially for the differentiation of tasks and task components during the whole course of later work. This gross taxonomy differentiates between information conserving tasks (one-to-one mapping of stimuli to required responses, as in discriminative reaction time tasks and short-term memory tasks involving complete recall of messages), information reducing tasks (gating and filtering tasks involving selective attention to and/or selective coding of input information), and classification tasks (categorizing of input information).

During the last year, there has been an emphasis on delineating the process taxonomy required for understanding and prediction of performance characteristics. The reason for this emphasis on process is that even the simplest tasks employed in the information-processing laboratory have been found to involve a complex of processes. Several important instances supporting this generalization derive from the research of the past year.

1. Swensson, under the guidance of Edwards, has been investigating the cost of decision time in a choice reaction situation in an extension of earlier work on the project by Fitts on the speed-accuracy tradeoff in stimulus-oriented decision processes. This research denies a monotonic speed-accuracy tradeoff function in this task, and concludes that a stimulus-analysis process is characteristic of a set for accuracy while a response preprogramming set is characteristic of a set for speed, with these sets operating in an either-or mode.

2. Jahnke (NIH Post-Doctoral Fellow), in collaboration with

Melton, has made a series of studies of immediate recall of a series of 7 digits which do or do not contain a repeated digit (tests of the Ranschberg phenomenon). This is one of the simplest situations used to measure short-term memory, yet Jahnke has found evidence that, in addition to element recoding processes (grouping) which were already known to be superimposed on perceptual identification processes, there are separable processes of detection (of repetition), memory for the fact of repetition once detected, and memory for the item repeated once detection is assured. In studies of the retrieval of information from intermediate-term memory, Melton and his student associates have arrived at a similar partitioning of the processes involved in the free recall of words as a function of their repetition with different numbers of other words separating their two occurrences.

3. Martin and his student associates, and Goggin and Martin, have confirmed in a variety of task situations the earlier finding by Martin that recall of a learned response, when the S is presented with the cue for it, is contingent on the recognition of the cue as one having been experienced before. The implication of this is that associative learning involves both a stimulus recognition process and an association of cue and response, as well as the generally recognized "response learning" component. This generalization has been shown to hold for retrieval of serial associations in very-short-term memory by Lively (Ph.D. thesis), under the guidance of Melton. A unique element in a series of elements (e.g., a letter in a series of digits or vice versa), is no better recalled when the probe cue is the preceding element, but the element following the unique element is recalled with significantly higher frequency. This finding is interpreted as a consequence of the better recognition memory for the unique element, and of its position in the sequence, which is a pre-condition for the better recall of an associated element.

4. Bjork, and Pollatsek (Ph.D. thesis), have demonstrated the need for independent treatment of rehearsal processes and repetition effects in short-term memory, and Bjork has gained evidence that there is a process whereby Ss may selectively forget some information in short-term memory, given the appropriate instructions. This phenomenon has interesting implications for the storage and processing characteristics of human short-term memory. The two most likely hypotheses as to the nature of this cognitive operation appear to be (a) that Ss upon receiving the forget signal stop any further rehearsal of the items they are told to forget, or (b) that Ss code the to-be-remembered items that follow the "forget" signal in some way that differentiates them from the "forgotten" items and accomplishes a kind of functional forgetting although all items are actually in memory. Further understanding of this phenomenon will, therefore, increase our understanding of rehearsal processes, coding process, or both.

5. Wattenbarger, and Cohen, under the supervision of Pew, have gained evidence in the visual search task that the occurrence of serial or parallel information processing modes is a function of the level of practice, the set for speed or accuracy of response, and the size of the set of target stimuli being searched for. In a similar vein, Reicher (Ph.D. thesis), under the guidance of Melton, has discovered that the perceptual processing of letters of a word from the information remaining in the preperceptual visual store appears to be a parallel processing of each letter of the word, which means that serial processing is limited to information "chunks" and does not apply to information elements.

All of the above has indicated to us that the most fruitful approach, if not the only valid approach, to construction of an operationally useful information handling task taxonomy is through delineation of the

process composition of important varities of information handling tasks (and their sub-varieties), and this will be the principal emphasis of future work. Also, it seems clear that nominally different tasks may have substantial overlap in process characteristics. Thus, identifiable short-term memory processes appear to be involved in a wide spectrum of tasks (search, reaction time, choice reaction) where its involvement was not previously stressed, and recognition memory processes seem to be even more widely involved in information processing tasks, but especially in any task involving the cued retrieval of information from short-term or long-term memory.

Selective Information Handling Processes

Selective Responding to Stimuli.--In 5 experiments involving a variety of payoffs for speed and accuracy of performance, Swensson (Ph.D. thesis with Edwards) has identified two distinct information-processing strategies: Stimulus processing (or analysis) and response preprogramming. By studying individual Ss in a variety of conditions it has been possible to identify the relative cost of time and errors that will make Ss ambivalent between the two strategies. Thus, when speed is subjectively more important than accuracy, responses are chosen prior to stimulation and released upon detection of the presence of a (any) stimulus. When this type of processing is required, the emission of the response is under the Experimenter's control and there is no trade-off (negative correlation) between the speed and accuracy of responding. Accuracy is at a chance level. But when accuracy is subjectively more important, in almost all cases the S takes variable amounts of time to "buy information" from the stimulus display, thus placing response emission under the S's control and inducing the familiar speed-accuracy tradeoff relation. These results constitute a new and large

step toward delineating relations among (a) differential utilization of alternative processing strategies under the operator's control, (b) differential receptiveness to signal events, and (c) the external circumstances that control these options.

Human Adaptive Capacities in Optimizing Performance.--During this report period additional evidence was obtained which strongly emphasizes human adaptive capacities in optimizing performance in information processing tasks. Swensson, in the work partially described above, had occasion to vary the probability of the stimuli to which the learners responded. As the probabilities of the stimuli became more unbalanced, that is, in situations where some stimuli became more likely than others, the learners were more likely to use the response-preprogramming strategy as opposed to the stimulus-processing strategy. Moreover, the response most frequently chosen under these conditions was invariably the response appropriate to the higher probability stimulus. Thus, even though a set for speed induces a response strategy that precludes immediate evaluation of the stimulus beyond simple detection, this set is nevertheless adaptive to probabilistic contingencies in the environment. In other words, an attempt to optimize performance at one level (using the stimulus as a trigger event for an already-chosen response) can be coincident with an optimizing attempt at another level (using memory for relative frequencies in making the response choice). The point is that adaptation capacities may be expressed at more than one level of analysis simultaneously. What varying the costs and payoffs for speed and accuracy appears to do is to variously weight the adaptive value of these several levels of analysis.

Triggs, in a Ph.D. thesis in preparation under the guidance of Pollack and Pew, has examined the mutual interaction of responses to signals

closely spaced in time. This work was done in the context of the "psychological refractory period" which has been used to argue for strict single-channel models of information processing. Several experiments investigated the use of differential instructions regarding the speed of response to the two signals, the temporal structure of the sequence, and the effects of practice. It was found that Ss can allocate processing capacity between the two reactions, and that active preparation can take place for the second reaction prior to emitting the first response. The reaction time to the first signal was shown to depend on the nature of the reaction required to the second stimulus, and the evidence suggests that a decrement in performance on the first reaction was accompanied by an increased level of preparation for the second reaction. Finally, sequential effects which are identified with the psychological refractory period decreased with practice. In short, the interactions of response times to signals that arrive with short intersignal intervals and which in the past have been interpreted as evidence for a single-channel information processing system, may be drastically modified by the nature of the responses, the opportunity to prepare for them, and practice. Triggs' conclusion is that the human can allocate processing capacity between tasks, rather than act in a strictly serial mode. It is of some interest to note that the conclusion of early research on short-term memory under Contract AF 49(638)-1235 was that Ss allocate processing capacity between rehearsal of the to-be-remembered unit and performance of the task used to "fill" the interval before the retention test.

The modification of the process characteristics of performance, as well as the speed and accuracy of performance, with practice has been

repeatedly demonstrated in studies during the year. The data of Triggs are relevant, as are the several lines of evidence briefly indicated in the preceding section on the taxonomy of information handling processes.

It must not, however, be thought that the human always optimizes performance. This versatility of the human information processor manifests itself only on certain occasions. For example, in the research of Bjork and Abramowitz of paired-associate learning, the Ss clearly do not optimize their probability of a correct guess when they cannot recall the correct response. There is a significant tendency to perseverate on an incorrect response over trials. Also, in numerous project studies of proactive inhibition in short-term memory, Ss have been observed to use one response correctly in one instance and then to use the same response erroneously as a guess in the next. These facts raise the question as to the determining task characteristics that permit multi-level optimizing of performance.

Decision Theoretic Interpretations of Information Processing Performance.--The experiments of Swensson summarized above were intended to test some of the implications of the "random walk" model of choice-reaction-time data, as suggested earlier by Fitts (1966). This model is an adaptation of a Bayesian statistical decision model for information purchase, for which Edwards (1965) worked out the formal model for the two-choice situation. The model assumes that the S begins each trial with prior odds as to the identity of the forthcoming stimulus. When the stimulus in fact appears, the S is conceived of as "purchasing" successive samples of the information available in the stimulus, at a fixed cost (in time) for each sample, until his subjective odds as to the identity of the stimulus reaches a pre-set criterion, at which point he responds. This model predicts a continuously variable

tradeoff between response speed and response accuracy as the experimenter changes the relative costs for errors and sampling time (i.e., as the experimenter varies a speed-accuracy cost-payoff matrix). As has been reported above, however, this description of the S's performance is appropriate but incomplete. The Ss appear to make first a high-level choice as to strategy, i.e., whether to be stimulus identifiers or stimulus detectors. This decision is made subjectively on the basis of expected value according to a payoff matrix. As long as the S is in the stimulus identification mode the model adequately predicts the speed-accuracy tradeoff, but not otherwise.

Information Storage and Retrieval

Modeling of Short-Term Memory.--Several lines of research that are directly relevant to the modeling of short-term memory were advanced to a significant degree during the year.

1. Recognition vs. Recall: Research completed and published by Martin (1967, 1968), and other studies now in press indicate that the to-be-remembered units are processed differently according to what their task-required use is to be. When an alphabetic unit serves only as a cue for the recall of a paired unit, the former is encoded only in part. This is shown by data from paired-associate experiments wherein although stimulus recognition becomes perfect and certain over trials, stimulus recall remains partial and uncertain. Earlier work by Martin and Melton on Contract AF 49(638)-1235 has shown that when recognition per se is the object of the experiment, those units that are easily fractionable (encodable by parts) are more difficult to recognize and give rise to more false recognitions. These results attest to the selective basis of recognition, as opposed to

the integrative nature of recall. In other words, the conventional superiority of recognition over recall is traceable to the selectivity of perceptual coding and the absence (in recognition) of a requirement for complete redintegration of the physical (or nominal) stimulus.

2. Internal Structure of the To-Be-Remembered Stimulus: Research on the role of internal structure or organization of material to be remembered has been extensive during this reporting period. Goggin and Stokes have examined the question of whether a learning task is easier in the long run if it is attacked en toto or if it is learned as a sequence of subparts. The experimental variable of importance is the degree of organization of the whole. The materials were various approximations to English word order. At low approximation, where sequential probabilities are low, the part method is clearly superior, presumably because the learner can more easily impose a subjective organization on smaller segments of the materials to be learned. However, as the material becomes more like ordinary English, the learner can make use of the grammatical structure already extant in the material, and the part method of learning loses its superiority. The implication is clear and fits nicely with other research on subjective organization of to-be-remembered material: in the absence of sequential dependencies, learners will evolve their own organization; and this is easier when the total amount of material is studied in segments.

Using another form of internal organization, Shulman and Martin have shown that items within a list of words are differentially recallable according to whether or not they are categorizable into concepts. What is important, however, is the fact that categorizable words appear to support each other in recall and not elicit their supraordinate concept. Several converging aspects of the data indicate, in agreement with the work reported

just above, that the organizational basis of recall is sequential dependencies among the items. This conclusion opposes the view that recall is controlled by a hierarchical classification scheme.

Jahnke(Special NIH Post-Doctoral Fellow) and Jahnke and Melton (to appear in Proceedings of APA Meetings, 1968) have completed five experiments on another facet of internal organization, known as the Ranschberg effect. Given a serial list of symbols to remember, the question is, what is the effect on retention of repeating one of those symbols within the string? This simple form of serial structure induces interesting effects which carry theoretic implications for modeling the STM process. Initially, three questions were asked: (1) Do Ss detect the occurrence of redundant elements? (2) Given detection, can they remember that the input contained such a redundancy? (3) How good is their memory for the specifics of the redundancy? Most of the results are in the stage of analysis, but two conclusions appear assured: First, S frequently fails even to detect the fact that there is a repeated item in the input, which fact, of course, sets him against emitting a repetition in recall; second, given detection, S frequently forgets which item was repeated, as evidenced by his repeating an item in recall that was not repeated in presentation. These findings force an important point, namely, that planned redundancy in signals can be beneficial only when detected by the receiver, and therefore that a key aspect of improved recall due to redundancy must be a learned expectation for the form of redundancy. In other words, repetition per se is of no value to the human information processor unless he knows ahead of time the nature of the redundancy. Jahnke's results indicate that the Ranschberg effect, which is a higher error rate in the recall of strings with redundant elements, as compared with those with no redundant element, is a combination of the errors

resulting from failure to detect the redundancy and errors resulting from failure to remember the identification of the redundant element at the time of recall.

Another study directly relevant to the modeling of short-term memory is a Ph.D. thesis by Lively (under the guidance of Melton) on the von Restorff effect in very-short-term memory. The von Restorff effect is the alleged better retention of a unique element (e.g., a digit in a string of letters) in an otherwise homogeneous string of elements. Some theorists have maintained that very-short-term memory (or "primary" memory) suffers interference that is determined by the number of intervening events, without regard for their similarity to the to-be-remembered event and its relations with preceding and succeeding events. Lively's study used a string of 10 digits or consonants presented at a fast rate, and the retention test was limited to the presentation of a single element from the string (the "probe"), with S under instruction to recall the element that followed it in presentation. Some strings of digits contained one letter, at various positions within it, and some strings of letters contained one digit. The recall of the unique element, given the presentation of the non-unique element that preceded it as a probe, was no better than the recall of its control; however, the recall of the element that followed the unique element, given the unique element as a probe, was significantly better than its control. It seems clear that such very-short-term memory is influenced by the similarity variable, but that its effect is principally on recognition memory rather than recall. The argument for this conclusion uses Martin's evidence (see previous section on Recognition vs. Recall) that recall of the second of two paired terms is conditional on the recognition of the first term as having occurred. This interpretation requires a check experiment on short-term recognition

memory in the Lively task situation, which will be performed.

Ligon (see attached Report No. 08773-19-T) completed a Ph.D. thesis (under the guidance of Melton and Bjork) in which very-short-term memory was again examined to determine whether it was, as some allege, free of proactive and retroactive interference effects based on similarity of elements. Her experiments show strong evidence of both the presence and amount of similar prior and interpolated material on very-short-term memory under conditions of very high rate of processing of input stimuli. A mathematical model to account for Ligon's findings is being developed by Bjork and Ligon.

Most of the research on grammatical factors carried out by Martin, Roberts, and Walter is concerned directly with the internal structure of to-be-remembered messages. Two experiments completed during this period demonstrate, by different methods, that when listeners are required to recall a structured, grammatical message, they selectively distribute their attention over the various parts (words) of the message and thereby determine, *at the time of input*, what aspects of the message enter STM. Roberts has shown further that this selective processing is sensitive both to the particular grammatical structure that obtains for the incoming message and to the serial position of the words in the string. It has also been noted that although the various classes of words react differently among themselves, the word-class effects found in such procedures as that of Cloze (blank completion) do not resemble those found in procedures where the whole sentence is presented for memorization. Thus the structure of the input materials is utilized quite differently depending upon the task.

In summary, any model of short-term memory seemingly must treat the following considerations: (a) Whether or not the input material is structured

(or redundant) in such a way that the learner makes a response of some sort (detection, recognition, to that structure; (b) whether the elements within a to-be-remembered string are homogeneous (on some dimension detected by S) or contain uniquely different elements; (c) whether the elements that precede the to-be-remembered element(s) in the stream of information processing, and also whether those that follow it and precede the moment of recall, are similar to or different from the to-be-remembered element, and how many (and perhaps where, in relation to the to-be-remembered unit) there are; (d) the interactions between redundancy detected and the amount of information to be stored; and (e) the subjective modes of structure generation by S when the information input overloads memory. Although objective (nominal) organization of stimulus material has an effect on short-term memory, it is clear that the process characteristics of short-term memory cannot safely be inferred by simple manipulations of objective organization of the input material. It is also clear that very simple models of short-term memory, such as those that employ the notion of a "push-down store," must be inadequate.

3. Repetition Effects: It has been evident for many years that repetition of to-be-remembered information improves recall; that is, no one denies that any model of short-term memory must somehow account for the effect of frequency of repetition. But to represent repetition effects in a model of either short-term memory or long-term memory as a simple additive effect of frequency, i.e., as a simple counter variable, has proven naive. The data of Jahnke, previously cited, is a case in point; however, the most persuasive data come from experiments which show that two presentations of an item have widely different effects on recall (or recognition) as a function of the number of other items that intervene between the two presentations: within as yet undetermined limits, the greater the number of intervening

items between presentations, the <u>greater</u> the probability of recall of the item.

Melton, Shulman, and Adams have conducted a series of experiments on this problem during the year, after discovering, during the preceding year, that the generalization stated above held for the immediate free recall of unrelated common nouns--a situation that Waugh and others elsewhere had alleged to be an instance of the operation of repetition as a simple frequency counter variable. Our results indicate that the "distributed presentation effect" (DPE) held for long lists of nouns (48 different words) when presented at rates of 1.3, 2.3, and 4.3 seconds per word, when the words were of mixed word classes and frequencies of occurrence (as achieved by random selection from a dictionary), and when presentation (at 1.3 sec. per word) was visual or auditory. The effect was also obtained with lists of 25 consonant-vowel-consonant trigrams of high and low association-value, being greater for the high association value. Further, it was determined that, when recognition of repetition was measured during list presentation, the DPE was not dependent on the <u>S</u> having recognized the repeated word as repeated, although the absolute probability of recall was greater at all interpresentation intervals if the <u>S</u> recognized the repetition. False recognition of repetition of once-occurring items had the interesting effect of depressing the probability of recall of those items. Finally, a detailed analysis of recall protocols gave evidence that <u>S</u>s were subjectively organizing the words into what has been called "adopted chunks" (i.e., recall of adjacent items in presentation adjacently in recall). These data have suggested the hypothesis that the DPE in free recall of words and trigrams occurs to the extent that the two occurrences of an item permit (or encourage) the coding of a repeated item with non-overlapping context words. The data are consistent with this hypothesis and

more direct tests are in progress.

The fact that delay of repetition enhances the effect of frequency of occurrence, and the hypothesis that the effect of delay is mediated by increasingly distinctive contexts (which become increasingly supportive of item recall in an additive sense), implies that if the full effect of a single context could be realized in one presentation, an <u>identical</u> re-presentation will add nothing to the probability of recall. An approximation of this prediction is provided by an experiment by Bjork and Abramowitz. Here, pairs of items were presented. But in testing for recall, the first member of the pair served to cue the second. When simple short-term-memory effects are discounted, it turns out that immediate repetition is markedly inferior to spaced repetition. (It is clear, however, that an idealization of the above prediction can never be effected; for the internally-supplied context cannot be held constant.)

Thus the role of repetition in an STM model is intimately bound to organizational factors. Repetitions provide opportunity for encoding, and hence repetition effects reduce to the problem of encoding variability. Perhaps the initial, at least, potency of this theoretic notion lies in the fact that it gets us off the perennial hook of viewing repetition as if it were a simple frequency counter variable.

4. <u>Stimulus Change</u>: Theoretic responding to the products of our research is, of course, a continual, ongoing activity of the project staff. Ordinarily, however, these exercises are not reported until such time as experimental evidence accrues either to their support or to their definitive rejection. But there is one hypothesis that deserves mention here because it continues to loom large in our theorizing about short-term memory. We

look with favor on the idea that the observed short-term forgetting function is actually the result of recovering memory for interfering material that was not presented but nevertheless belongs to the same class as the item actually presented. In other words, we feel that when an item is presented to memory, what happens is that while the item itself is certainly registered, its associates are simultaneously inhibited. As time elapses, these associates recover their strength and interfere with successful selection of the target item to be recalled. From this view flows an implication that has met with impressive success.

Following the lead of earlier work by Wickens, Melton and his students have shown that with successive short-term memory tests for items in the same conceptual category (e.g., consonants or digits), recall for the target item of the moment declines. This is to be expected under the assumption that continuous activation of that category serves to cumulate suppressive inhibition. If the conceptual category is now changed (e.g., from consonants to digits), no suppression is observed on the first short-term memory test, but suppression again accumulates with exercise of the new category. Thus, repetition has produced mitigation of availability on a category-wide basis. Moreover, this cumulative inhibitory effect is clearly limited to the category to which the presented items belong. This last is further confirmation of the role of contextive structure in short-term memory, where in this case the context is assembled conceptually by the S over time.

The result just reported may be viewed from another, but equivalent, angle: A change in the stimulus situation is preventive of the interference that might otherwise have transferred to it. It is well known that to the extent that two learning situations are similar, incompatible responses attached to them separately will interfere with each other. In previous research, the similarity between two successive learning situations has been

varied in terms of the nominal stimulus, while possible subjective variations in the functional stimuli have been ignored. The problem faced by Goggin and Martin was whether or not it is possible to show that although the nominal stimuli of the two tasks of an interference paradigm are identical, the functional stimuli actually used by the S are quite distinct. In a two-stage paired-associate experiment (AB, ABr), three different groups of Ss learned the two tasks under the following conditions: (1) forced to use the same one of the two orthogonal dimensions that characterized the stimuli in both tasks; (2) forced to use one of the stimulus dimensions in the first task, the other in the second task; and (3) forced to use one of the dimensions in the first task, but free to use either in the second. Following the learning of these two tasks, the Ss were tested for their retention of the first-task associations. Only those Ss who switched dimensions were found to be free of the interference nominally implied by the paradigm. This means that if the S is able to change his functional encoding of the stimuli (and in fact does so) during second-task learning, he can avoid the inhibitory interaction of incompatible associations. Thus we consider it established that even when nominal stimulation is held constant, functional stimulus change can occur to the protection of information in memory.

Further evidence on the idea that even though nominal stimulation remains invariant, Ss will nevertheless alter functional stimulation comes from research completed by Martin and Roberts. Again using a paired-associate interference paradigm (AB, ABr), sentences served as stimuli, digits as responses. In both tasks, test trials on which the digit responses were required to the sentences were intermixed with test trials in which the digits were required to the individual words that comprised the sentences. During learning of the first task (AB), there emerged a definite distribution of correct

digit responses to words (e.g., nouns eliciting most correct responses, adverbs fewest). During learning of the second task (ABr), this distribution shifted so that nouns retained superiority over adverbs, but verbs gained markedly in prominence. In other words, the functional element shifted from primarily nouns in the first task to a combination of nouns and verbs in the second. There are other, converging aspects of the data that affirm this conclusion, and the experiment had other purposes; but suffice it to repeat that no model of short-term memory can ignore the selective processing of input stimuli--while ostensibly the stimulus situation appears invariant to the observer, in fact it is being manipulated by the *S* to his own advantage.

5. Intervening Activity: A factor that is of paramount importance in predicting recall probability is the nature and extensiveness of activity intervening between presentation and recall. This matter has been investigated as reported above, where stimulus change as perpetrated by the *S* himself was studied. Most research on the activities interpolated between presentation and recall, however, has involved experimenter control of those activities.

In an experiment by Pollatsek (Ph.D. thesis, under the guidance of Bjork), three-word stimuli were presented and short-term memory was tested after various combinations of intervening activities: PRIT, PRIPRIT, and PRITRIT, where P indicates presentation of the trigram, R and I indicate rehearsal and interference activities, and T indicates a recall test. Several effects of importance emerged. (1) The effectiveness of a second presentation is an increasing function of the time since the first presentation, even when the interim is occupied by an interfering activity. (2) A rehearsal period following the first presentation of an item is more effective in sustaining memory for that item than a comparable period following a second presentation. (3) Rehearsal seems to do more than simply delay the time that forgetting

begins; it increases the to-be-remembered item's resistance to interference. Thus, by arranging for different schedules of occurrence of rehearsal and interference, Polletsek has shown that certain classes of short-term-memory models, those incorporating simple decay notions, are not reasonable; that rehearsal is not a simple storage program, rather an interactive process; and that the effect of repetition depends not only on the number of intervening events but also on their nature. This research, like most of the other experiments carried out during this reporting period, constitutes an item of progress on two counts: (a) the grip of those simplistic theoretic notions that have constrained the verbal learning and memory area for decades has been substantially dispelled, and (b) the factors that must play a major role in any short-term-memory model are being brought into sharp focus. It is becoming obvious that the older tradition of simple theory and complex experimentation is being overturned for the more realistic approach of complex theory and simple experimentation.

Refinement or Resolution of Certain Critical Issues

1. Serial Versus Parallel Memory Search: A continuing issue in memory theory is whether subjects search for a target item in their memory in a serial or a parallel fashion. Thus if a subject is remembering four items of information and is presented with a probe item (which may or may not be one of the items in memory), does he check this probe item serially, one-by-one, against the four items in memory or does he examine all four simultaneously. An answer to this question is imperative on theoretic grounds; for the answer will determine which of several plausible theoretic routes is to be taken in explaining such facets of recall as response latency, distribution of intrusion and confusion errors, and outright failures.

Pew and Wattenbarger have been attempting to delineate the conditions under which a parallel search of immediate memory can occur. Earlier research outside our laboratory (Neisser) has indicated that practiced subjects, under instructions that emphasize speed, are able to search memory for 10 target items as easily as for one. Wattenbarger and Pew have replicated this result. However, when accuracy is emphasized, subjects were unable to search their memories even for five targets as rapidly as for one, even with extensive practice. Thus with a speed set, the memory-search process can at least come to look as if it were a parallel process; but with an accuracy set, the memory-search process looks decidedly serial. This result indicates, as do the Swensson-Edwards results reported in an earlier section, that there exists a hierarchical strategy selection procedure, where certain task demands activate one mode of searching, other task demands activate another. It is clearly evident that information processing in the human is decidedly nonlinear and easily modifiable as to mode by task requirements.

But the foregoing result notwithstanding, that is, even though practiced subjects could not search for five as rapidly as for one target in memory under accuracy instructions, there emerged the concomitant fact that they could search for 10 as easily as for five. Thus the sequel problem is whether or not search for a single target is qualitatively different from multi-target search. An experiment by Pew and Cohen answered this question by varying the size of the target set in memory: 1,2,3,4, or 5 items. They found that the memory search time, under an accuracy set, was a monotonically increasing function of the size of the set, with no apparent discontinuity between sets of size one and two. Thus the resolution is that the search process for a single item is not qualitatively different than that for multi-targets.

2. Action of Repetition: The action of repetition has been reported at length in earlier sections. Iteration of the conclusions at this time are, however, in order. Point: It is no longer theoretically expedient to represent repetition effects in a model of memory by a simple frequency counter variable. Repetitions provide opportunity for contextive encoding, which encoding is protective against interference. The research completed during this reporting period has been extensive and has converged sharply on this point. A corollate of this point is that future research for further explication can be simpler in design and concentrate on the effects of as few as one and two repetitions. It is well known in science that simplification in research paradigms is perhaps the single largest factor in theoretic progress. Other advances notwithstanding, this particular advance marks this reporting period as being especially fruitful.

3. Identification of Stimulus Encoding Modes: Work on the identification of various modes of encoding to-be-remembered stimuli, and an assessment of the effectiveness of these modes, has also been extensive during this period. For the most part, this work is concomitant with work on other problems, such as stimulus change and repetition effects. In situations where the several inputs to STM are ostensibly independent, subjects will encode these materials in an interlocked, contextive way, thereby permitting each item both to be recalled for its own sake and to serve as a supporting cue for other items. On the other hand, when an item is to serve only as a cue for recall of another item, subjects readily reduce the totality of the cue item to a selected few of its features, thereby enhancing its discriminability as a cue but also essentially ensuring its non-recallability. We have also reported various experimental conditions that affect the mode of encoding that is adopted by the subject, which results indicate a hierarchical

adaptive system that allows for optimizing of performance on several levels. Ordinarily we call the subjective weighting of the various levels of responding/analyzing of input stimuli a decision process.

4. Interface Between Perception and Memory: This proposal topic is now seen to be either included under the preceding topics, or inclusive of them. This realization is one of the thinking shifts produced by this year's activities. By perception is meant the residue of sensation after such operations as orientation and contrast filtering have been imposed. The point that can be induced from this year's activities is that both task demand and task experience control selective processing of raw input, and that only the results of this selective processing are entered in STM. Reference to several experiments not reported above (but completed during this reporting period) will nicely illustrate this point.

a. Martin has demonstrated that in a multidimensional concept identification task, where only one of several dimensions is relevant for solution, the Ss selectively emphasize the processing of that dimension. A memory test for stimuli just seen indicates that although the S in fact sensed all aspects of each multidimensional stimulus (because the several dimensions combined to produce a single symbol), they nevertheless processed and had memory for the relevant feature only; memory for irrelevant features of a just-seen stimulus was strikingly poor. Thus the evidence for perceptual emphasis of relevant dimensions that has been accumulating since the time of Külpe is reflected also in a STM test.

b. The grammatical studies of Roberts and Martin have shown that even when immediate verbatim recall of an ordinary English sentence is required, there appear systematic deletions and substitutions of certain word classes. That these systematic differences appear at full strength in immediate recall

and maintain themselves throughout the various retention intervals indicates that selective perception has dictated the contents of STM and that STM has maintained the differences imposed upon it at the time of input.

c. Lest it be over concluded that the interface between perception and memory is relatively unencumbered, it is well to emphasize that subjects are perfectly capable of further, directed operations on material already successfully placed in memory. I. Bennett and Melton have gathered evidence on mediative aids generated subjectively by subjects, mediative aids that facilitate links between items in memory. And strikingly enough, Bjork has shown that when instructed, subjects can "dump" information from memory, thereby clearing from its registers items that in other situations provide interference in recall.

In summary, the interface between perception and memory is dissolving under experimental attack into one of two possible cases: Either it disappears from our consideration in the sense that what is perceived is stored, thereby shifting the emphasis to the factors that control selective perception, or it becomes the dominant problem in memory research in the sense that what is perceived is what determines such further encoding processes as context embedding and mediative association formation. Which route will be followed depends on ongoing interchange of theoretic ideas among project staff. The former route is probably preferable because it recognizes the role of memory in selective perception and does not presuppose an almost unthinkable number of cognitive operations. Moreover, the former route makes tenable a substantial number of links with such other areas as perception and the generalizations being offered by psychophysiologists.

5. <u>Interference in STM Traceable to Categorizing and Recoding Processes</u>: Once an item is registered in STM it may be operated upon, but not

always in such a way as to facilitate its retrieval at the time of recall. I. Bennett and Melton asked subjects in a Peterson STM to describe any mnemonics they had used in attempting to retain a given input. Whenever a mnemonic was specified, their report was compared with their actual recall output. While facilitation was certainly isolated in a number of cases, in others there appeared a decrement. For example, a given mnemonic might itself be recalled instead of the original input; and sometimes the mnemonic process, while facilitating preservation of the input items per se, nevertheless obliterated order information. This type analysis exemplifies the idea that although by the standards of an "impartial" external observer the subject makes errors, by the subject's own criterion he is behaving in accordance with the machinations of his memory process. This means, of course, that error patterns are a more revealing source of information regarding that memory process than are correct recalls. This view underlies the prevalence of error analyses in the STM program and the growing interest in asking experimental subjects for verbal reports of what they think they were up to during the experiment.

As mentioned under other topics of this report, the process for encoding grammatical messages frequently gives rise to overt errors, where by "error" is meant failure of verbatim recall. In the encoding process there occur substitutions for words (usually nouns and verbs) that are traceable both to synonymity and to associations activated by other words in the input. Again, however, it is of doubtful wisdom to treat these events as errors; for from the subject's point of view, they are the result of the way his memorial process operates.

Refinement of STM Methods and Measures

Two refinements in STM procedures are worth noting here. The first has to do with a measure that has been introduced by Melton and is being developed further. It consists, in principle, of an index of context involvement around a particular recalled item. The contiguity organization attaching to a given item in recall reflects the degree to which that item was encoded in conjunction with neighboring items at the time of input. This technique of analysis has contributed heavily to our understanding of what a repetition accomplishes and has established a link between Jahnke's Ranschberg research and Melton's free-recall research.

The second has to do with a technique for establishing arbitrary conceptual categories independently of the recall situation. In an earlier reporting period, Martin and Melton used the choice-reaction time paradigm to induce artificial processing categories of independent stimuli. Then these same stimuli were recombined in various ways and tested for retention in a STM paradigm. An interaction of conceptual categories in recall was observed. The promise of this technique lies in its relative freedom from influence of pre-learned classifications. Both the size and the strength of such categories can be manipulated at will without the presence of extenuating associations and linguistic responses that otherwise complicate research.

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Human Performance Center, Department of Psychology University of Michigan, Ann Arbor, Michigan	2a. REPORT SECURITY CLASSIFICATION Unclassified
	2b. GROUP

3. REPORT TITLE

HUMAN INFORMATION HANDLING PROCESSES

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Scientific --------- Interim

5. AUTHOR(S) (First name, middle initial, last name)

Arthur W. Melton

6. REPORT DATE June 1968	7a. TOTAL NO. OF PAGES 39 + iii	7b. NO. OF REFS
8a. CONTRACT OR GRANT NO. AF 49(638)-1736	9a. ORIGINATOR'S REPORT NUMBER(S) Memorandum Report No. 4 08773-21-A	
b. PROJECT NO. 920F 5002		
c. 6154501R	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) AFOSR 69-0486TR	
d. 681313		

10. DISTRIBUTION STATEMENT

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11. SUPPLEMENTARY NOTES TECH, OTHER	12. SPONSORING MILITARY ACTIVITY Air Force Office of Scientific Research 1400 Wilson Boulevard (SRLB) Arlington, Virginia 22209

13. ABSTRACT

This is a review (annual report) of research carried out on human performance in information processing and memory at the Human Performance Center, Department of Psychology, University of Michigan, under Contract No. AF 49(638)-1736. Experimental results and theoretic progress are presented on the following topics: Taxonomy of information handling processes; Selective information handling process (which includes Selective responding to stimuli, Human adaptive capacities in optimizing performance, and Decision theoretic interpretations of information processing performance); Information storage and retrieval (which includes Modeling of short-term memory); Refinement or resolution of certain critical issues; and Refinement of short-term-memory methods and measures.

DD FORM 1 NOV 65 1473

Unclassified

KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
1. Information Processing						
2. Human Performance						
3. Memory						
4. Short-Term Memory						
5. Recognition Memory						
6. Selective Attention						
7. Decision Processes						
8. Performance Factors						